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ABSTRACT

The calculation of the F statistic for a one-factor analysis of variance (ANOVA) and the construction of an ANOVA tables are easily implemented on a spreadsheet. This paper describes how to compute the p-value (observed significance level) for a particular F statistic on a spreadsheet. Decision making on a spreadsheet and applications to the classroom are also discussed for Lotus 1-2-3 for DOS or for Windows. Spreadsheets enable the learner to see what is calculated and how results are obtained, and they allow the user to automate statistical decisions. Spreadsheet use is particularly useful for students in that it creates conditions in which: (1) fundamental concepts and their meanings must be understood; (2) calculations can be automated; (3) meanings of the concepts are enhanced; (4) technology interference is minimal; (5) many examples can be studied; (6) decision making becomes the focus of learning hypothesis testing; (7) decisions about hypothesis testing can be made in different ways; and (8) changing the values on a worksheet recalculates the entire worksheet with results adjusted automatically. An appendix discusses a particular function of the Lotus 1-2-3 software for Windows. (Contains three tables and seven references.) (SLD)

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FINDING P-VALUES FOR

F TESTS OF HYPOTHESIS

ON A SPREADSHEET

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INTRODUCTION

Hypothesis testing in elementary statistics by hand computation or by calculator is very tedious and for some students overwhelming. Using computers eases these computations and makes learning hypothesis testing more meaningful and relevant.

A spreadsheet for conducting an analysis of variance (ANOVA) is easily constructed. There is no magic box for computation of output, the student connects calculations to concepts and sees correct processes and results.

The calculation of the F statistic for a one factor ANOVA and the construction of an ANOVA table are easily implemented on a spreadsheet. This paper describes how to compute the p-value (observed significance level) for a particular F statistic on a spreadsheet. Decision making on a spreadsheet and applications to the classroom are also discussed. Lotus 1-2-3 for DOS or for Windows can be used.

A CLASSROOM EXAMPLE

The following is an example used in my classroom.

Example. A researcher wishes to determine if there is a significant difference in three different training methods used for continuing education of a certain company's employees. Each training group contained 6 students. After some time, each group was tested. The grades for each individual were obtained and are listed in Table 1.

Insert Table 1 about here

F STATISTIC CALCULATIONS

A spreadsheet can be used as an electronic scratchpad for performing a one factor Analysis of Variance. Formulas necessary for calculating the F statistic are defined in [3]. Using these formulas for the F statistic, a template is made. This template can be expanded to 4, 5 or more groups with the copy or copy/paste commands.

Procedures for an Analysis of Variance (ANOVA) including stating hypotheses, setting significance levels, calculating test statistics, and making decisions are discussed. Calculations are performed by hand and then by spreadsheet. Comparing the critical F value and the calculated F value becomes the focus. (In the example, the F statistic 4.949 is greater than the tabled F value 3.68, and so the null hypothesis is rejected.)

P-VALUE CALCULATIONS

After various examples are studied where the critical and the calculated F values are compared, the concept of p-values and their use in decision making is presented. If p (the observed significance level) is less than or equal to alpha, (the significance level), reject null hypothesis otherwise fail to reject null hypothesis [3].

Various expressions that approximate p-values are found in [1]. Table 2 presents an approximation for the p-value of the F statistic. The area under the F distribution to the left of the calculated F is the percentile value while the area of the F curve to the right of the calculated F is the p-value or observed significance level.

After students have conducted a number of hypothesis tests with calculator and spreadsheet, examples are studied where decisions are made automatically (Table 3).

Insert Table 2 and Table 3 about here

The values for x and percentile apply two expressions found in [3] and [6]. They are: 1) $x = \dfrac{F^{1/3}(1-2/9d_1)-(1-2/9d_2)}{\sqrt{2/9d_1+F^{2/3}2/9d_2}}$

where d_1 and d_2 are the degrees of freedom for numerator and denominator respectively.

2) percentile = $1 - (1/2)(1 + a_1x + a_2x^2 + a_3x^3 + a_4x^4)^{-4} + |e(x)|$ where

$|e(x)| \le 2.5*10^{-4}$ and $a_1 = .196854$, $a_2 = .115194$, $a_3 = .000344$,

and $a_4 = .019527$.

Other expressions also approximate the percentile value and p-value.

CLASSROOM DISCUSSION

After doing some relevant examples in class, I use the following questions for additional classroom exploration.

1) What does rejection of or failure to reject null hypothesis mean?
2) As the significance level varies, what happens to the decision of rejection or failure of rejection of null hypothesis? If alpha increases or decreases what happens to the decision concerning the null hypothesis?
3) As the test statistic F varies, what happens to the decisions concerning the null hypothesis? As F gets large, what happens to the null hypothesis?
4) As degrees of freedom vary, what happens to the decisions concerning the null hypothesis?

CONCLUSIONS

Spreadsheet software is readily available and is useful for mathematics and applications courses such as business, statistics and physics. Many ways that spreadsheets can be used for learning mathematics are described in [2] and [4].

Spreadsheets enable the learner to see what is calculated, how results are obtained, and automate statistical decisions. (Table 2 and Table 3). Macros can further automate

decision making [5] and [7]. Similar techniques can be used for calculating chi-square, t, and z statistics.

Students using spreadsheets for tests of hypothesis learn that a) fundamental concepts and their meanings must be understood, b) calculations are automated, c) meanings of concepts are enhanced, d) technology interference is minimal, e) many more examples can be studied, f) decision making becomes the focus of learning hypothesis testing, g) concepts become relevant, h) decisions concerning hypothesis testing can be made in different ways, i) changing values on a worksheet recalculates the entire worksheet with results adjusted automatically.

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Table 1.

Training Techniques

	Group 1	Group 2	Group 3
	x1	x2	x3
1	78	77	70
2	76	77	71
3	73	72	66
4	76	67	69
5	82	72	67
6	77	76	78

Table 2

Approximation for P-values

	A	B	C	D	E	F
4		4.949	F value			
6		2	d1 degrees of freedom for numerator			
8		15	d2 degrees of freedom for denominator			
10			coefficients for approximation			
12		0.196854	a1	0.11519	a2	
14		0.000344	a3	0.019527	a4	
16		x	2.012			
18	percentile		.9780			
20	p-value		.022			
22	alpha		.05			
24	decision		reject null hypothesis			

Note: Formulas for calculations are provided in Table 3. The letters across the top represent columns and the numbers down the side are rows. A particular cell is represented by a letter and a number.

Table 3

Formulas for Approximation of P-values

A	B	C	D	E	F
4	4.949	F value			
6	2	d1 degrees of freedom for numerator			
8	15	d2 degrees of freedom for denominator			
10		coefficients for approximation			
12	0.196854	a1	0.115194	a2	
14	0.000344	a3	0.019527	a4	
16	x	(+A4^(1/3)*(1-2/(9*+A8))-(1-2/(9*A6)))*(2/(9*A6)+A4^(2/3)*2/(9*A8))^(-1/2)			
18	percentile	1-(1/2)*(1+A12*C16+C12*C16^2+A14*C16^3+C14*C16^4)^(-4)			
20	p-value	1-C18			
22	alpha	.05			
24	decision	@if(+C20<=+C22,"reject null hypothesis","fail to reject null hypothesis").			

Note: In cells A4, A6, and A8, enter values for F and the degrees of freedom. In cell C22, enter any alpha (significance level). In cells A20, A22, and A24 decision-making

concerning hypothesis tests using p-values is shown. Comparing the critical F and the calculated F can be automated similarly.

APPENDIX

ANOVA's by @FDIST Function

The p-value and the decision to reject or fail to reject null hypothesis can also be found by using the @FDIST function, available in LOTUS 1-2-3 for Windows. Table 4 displays the use of this function for the example described. Once the F statistic is calculated with degrees of freedom for numerator and for denominator respectively, decisions can be made to reject or fail to reject null hypothesis.

Table 4

@FDIST function:

	A	B	C	D	E	F
2	4.949	F statistic				
4	2	df for numerator				
6	15	df for the denominator				
8	.022	@FDIST(+a2,a4,a6)				
10	.05	alpha				
12	reject null hypothesis	decision				

Note. For the example given, the values are placed in this table. The cell formula for +a12 is @if(+a8<=+a10,"reject null hypothesis","fail to reject null hypothesis").